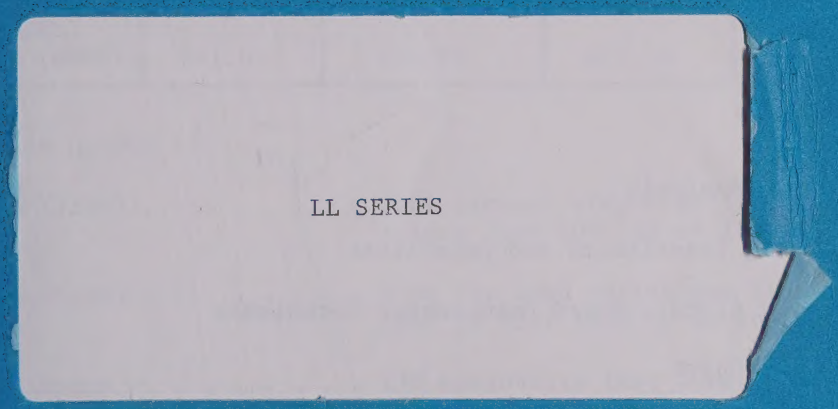
INSTRUCTION MANUAL

REGULATED POWER SUPPLIES



LAMBDA

LAMBDA ELECTRONICS CORP.–MELVILLE, L. I., N. Y.

INSTRUCTION MANUAL

FOR

REGULATED POWER SUPPLIES

LL SERIES

This manual provides instructions intended for the operation of Lambda power supplies, and is not to be reproduced without the written consent of Lambda Electronics Corp. All information contained herein applies to all LL models unless otherwise specified.

LAMBDA ELECTRONICS CORP. MELVILLE, L.I., N.Y.

MAIN PLANT TELEPHONE: 516 694-4200

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SPECIFICATIONS AND FEATURES

Specifications apply to all models. Performance specifications do not change for models with "OV" suffix.

DC OUTPUT--Voltage regulated for line and load

Voltage Range . . . . TABLE I

VOLTAGE RANGE

MODEL	LL-901	LL-902	LL-903	LL-905
VOLTAGE RANGE VDC	0-10	0-20	0-40	0-120

Current Range . . . . TABLE II

CURRENT RANGE, 0-50°C

MODEL	LL-901	LL-902	LL-903	LL-905
CURRENT RANGE (AMPS)	0-1.0	0-0.65	0-0.35	0-.065

REGULATED VOLTAGE OUTPUT

Regulation (line) . . . . . 0.01 percent plus 1 millivolt for input variations from 105-132 or 132-105 volts AC.

Regulation (load) . . . . . 4 mv for load variations from no load to full load or full load to no load.

Ripple and Noise . . . . . 250 microvolts rms; 1 millivolt peak to peak with either positive or negative terminal grounded.

Temperature Coefficient . . . . . Output change in voltage less than (0.015% + 300 microvolts)/°C.

AC INPUT--105-132 volts AC at 57-63 Hz. For input power see table III. Derate current 10% for 47-57 Hz input. For 63-440 Hz input, consult factory.

TABLE III

INPUT POWER*

MODEL	INPUT POWER
LL-901	30 Watts
LL-902	32 Watts
LL-903	32 Watts
LL-905	15 Watts

*With output loaded to full current rating and input voltage 132 volts AC, 60 Hz.

OVERLOAD PROTECTION

External . . . . . Adjustable, automatic, electronic current-limiting circuit, settable from 0 to 110 percent of rated current; limits output current to preset limit for protection of load and power supply when external overloads and direct shorts occur.

Internal . . . . . Fuse F1 provides protection against internal circuit failure in conjunction with the overvoltage protector option.

Fuse F2 protects the AC input circuit. Overload of the supply does not cause fuse failure.

INPUT AND OUTPUT CONNECTIONS . . . . . Heavy duty 5 foot, 3 wire line cord for all models; five way binding posts on right side of unit provide positive (+), ground and negative (-) DC output connections.

OVERSHOOT--No overshoot of output voltage under conditions of power turn-on, power turn-off or power failure.

OPERATING AMBIENT TEMPERATURE RANGE AND DUTY CYCLE--Continuous duty from 0°C to 50°C ambient. For operation at temperatures above 50°C, consult factory.

STORAGE TEMPERATURE - (non-operating) -40°C to 85°C

METER--Dual function meter measures voltage or current output as selected by meter function switch on front panel.

CONTROLS

DC Output Controls . . . . . Coarse and fine voltage controls and current control permit adjustment of DC output; located on front panel of all models.

Binding Posts (+) (-) (GND) . . . Five way binding posts on all models.

Meter Switch . . . . . Panel mounted switch selects voltage or current as measured by the dual function meter.

Power . . . . . Panel mounted switch and indicator light for all units.

PHYSICAL DATA

Size . . . . . 5-1/2" H. x 5-5/8" W. x 3-5/8"

Weight . . . . . 5 lbs. net; 7 lbs. shipping wt.

MOUNTING

Laboratory bench, table top . . . Lies flat or stands erect.

MODEL OPTIONS

"V" OPTION . . . . . Standard LL power supplies can be obtained for 205-265 VAC, 47-57 Hz input, derate current rating by 10%.

OVERVOLTAGE PROTECTOR ACCESSORY . . . Externally mounted, Overvoltage Protectors LC-OV-10, LC-OV-11 and LC-OV-12 are available for use with models LL-901, LL-901-OV, LL-902, LL-902-OV, LL-903 and LL-903-OV.

THEORY OF OPERATION

GENERAL

The Lambda power supply consists of an AC input circuit and transformer; a bias supply consisting of an auxiliary rectifier and filter, and pre-regulator*; a main regulator circuit consisting of the main rectifier and filter, a series regulator, emitter follower driver, a current comparator*, a voltage comparator*, an amplifier*, current and voltage sensing networks and a voltage reference circuit*.

* This circuit element is part of integrated circuit (IC1) in the supply.

The circuit arrangement is shown in block diagram form, Figure 2. The circuitry is discussed with reference to the block diagram and the schematic diagram.

FUNCTIONAL DESCRIPTION

Single phase input power is applied to transformer T1 through the input circuit which contains a fuse (F2) to protect the power supply against internal faults.

The main rectifier, a full wave rectifier, provides the power which is filtered by capacitor C6 and then regulated via a series regulator and delivered to the output. Half-wave auxiliary rectifier CR1 provides voltage filtered by capacitor C1 for the preregulator located in IC1. The reference element, powered by the preregulator, provides a reference voltage for the current comparator and the voltage comparator.

Constant voltage circuit operation is determined by changes in the load which cause a change in one input to the voltage comparator. A second input to the comparator is a reference voltage that is developed by a constant current of 1 milliampere flowing in divider elements R8, R15 and R16 (as applicable). The comparator compares the output voltage change with the reference voltage resulting in an error signal at the output of the comparator.

In constant voltage operation the voltage across R7 is less than the preset voltage across R6, causing the current comparator to be at cut off. If the load current decreases, causing a rise in output voltage, the voltage comparator conducts less and more current flows through the OR gate. This action causes the amplifier to conduct more heavily, reducing drive current to the base of driver Q1, causing the series regulator impedance to increase and the output voltage to decrease accordingly.

Current limit circuit operation is determined by changes in the load. The current comparator samples load current through current sensing resistor R7. When the voltage drop across R7 increases to the preset voltage reference determined by R9 and setting of R6, the current comparator conducts. Thus, when the output current rating of the unit is exceeded, the current comparator conducts, decreasing the current through driver Q1, resulting in an increase of voltage across the series regulator and a decrease of the output voltage, effectively limiting the output current to a safe value. The current limit value is determined by resistors R6, R9 and R7.

The following paragraphs apply only to "OV" suffix models.

Overvoltage Protection Circuit, functional description (See OV schematic diagram):

When the power supply increases above the voltage limit value set by the VOLTAGE ADJ. controls, Q102 is biased on. Q102 in turn biases Q101 on through resistor R104 causing Q102 to supply gate current to SCR-101. SCR-101 turns on and an effective short circuit across the output terminals is attained. This action causes the voltage at the power supply terminals to drop, protecting the load from excessive supply output voltage. SCR-101 conducts until the power supply is turned off, or until F1 opens.

OPERATING INSTRUCTIONS

CONTROLS, INSTRUMENTS AND FUSES

Power ON-OFF Switch. The power ON-OFF switch, located on the front panel, controls application of input power to the supply. When the switch is in the ON position, the red power indicator glows.

VOLTAGE ADJ. Controls. The VOLTAGE ADJ. controls consist of a coarse adjustment potentiometer, which varies the DC voltage over a range of 0-10, 0-20, 0-40, 0-120 volts as applicable, and a fine adjustment potentiometer, which varies the DC voltage over a 10%, of maximum output voltage, range. The total DC voltage output is equal to the sum of each shaft setting. The controls are located on the front panel of all units.

CURRENT ADJ. Control. The CURRENT ADJ. control, located on the front panel, varies the DC current over 110% of the rated current range. Clockwise rotation results in increasing current

DC VOLTS/DC AMPS (or as applicable, MA) Dual Function Meter. A DC output meter monitors the voltage or current at the output terminals for the rated voltage or current range. The meter operates in conjunction with the meter function switch.

METER, VOLTAGE/CURRENT Function Switch. Located on the front panel, the METER, VOLTAGE/CURRENT function switch selects either voltage or current modes of operation for the DC output meter.

Fuses. Fuse F1, located on the printed circuit board, provides protection against internal circuit failure. See schematic diagram for current ratings of F1 fuse.

Fuse F2, located behind the front panel, protects the AC input circuit.

Connection Terminals. Make all connections to the supply at the five-way binding posts located on the side of each unit. Apply input power through the line cord.

GROUND CONNECTIONS

The Lambda power supply can be operated with negative or positive output terminal grounded or with no terminal grounded.

> NOTE: When operating the supply with neither terminal grounded, high impedance leakage resistance and capacitance paths can exist between the power supply circuitry and chassis ground.

BASIC MODE OF OPERATION

This power supply operates as a constant voltage source provided the load current does not exceed the rated value. For continuous operation load current will remain limited to current limit value set by the CURRENT ADJ. control. With CURRENT ADJ. control set fully clockwise, minimum output current will be 110% of unit rating.

CONNECTIONS FOR OPERATION

Refer to figure 1 for proper supply-load connections.

DETAILED OPERATING PROCEDURES

SAFETY NOTICE

DANGEROUS VOLTAGES EXIST IN THIS EQUIPMENT. OBSERVE THE USUAL SAFETY PRECAUTIONS WHEN OPERATING OR SERVICING THE EQUIPMENT TO AVOID SHOCK OR INJURY.

Constant Voltage Operation, Adjustable Current Limit

1. Remove AC power to the supply and place power ON-OFF switch in OFF position before connecting load to the supply.

2. Connect power supply to load as shown in figure 1.

3. Turn VOLTAGE ADJ. controls fully C.C.W. and CURRENT ADJ. control fully CW.

4. Apply AC power to the supply via the 3 wire line cord.

5. Place ON-OFF switch in ON position and check that red power indicator is lit.

6. Place VOLTAGE/CURRENT meter function switch in VOLTAGE position.

7. Turn VOLTAGE ADJ. control knobs to the desired setting as indicated by the dual function meter.

8. Place VOLTAGE/CURRENT meter function switch in CURRENT position.

9. When current to the load must be limited to an intermediate value within the current rating of the supply, procede as follows:

   a) Remove load

   b) Short circuit output of the supply by connecting a jumper between (+) and (-) terminals.

   c) Slowly turn CURRENT ADJ. control C.W. until desired current limit value, indicated on the dual function meter*, is reached.

   d) Remove jumper and reconnect load.

   * When using the dual function meter in the current mode, a 1 milliampere offset from zero is indicated; this is the sensing divider current and not the load current. For load current use the 1 ma point as zero.

10. Power supply is now in proper operation.

FUSE SHUTDOWN

Internal component failure is prevented by fuses which protect the components from damage caused by excessive currents. Fuses will blow when the maximum rated current value for the fuse is exceeded. Fatigue failure of fuses can occur when mechanical vibrations from the installation combine with thermally induced stresses to weaken the fuse metal. Many fuse failures are caused by a temporary condition and replacing the blown fuse will make the fuse protected circuit operative. When the LL unit is used with the overvoltage protector accessory, or "OV" suffix models are used, fuse F1 will provide protection against internal component failure.

MAINTENANCE

GENERAL

This section describes trouble analysis routine, replacement procedures, calibration and test procedures that are useful for servicing the Lambda LL power supply. A trouble chart is provided as an aid for the troubleshooter. Refer to the section on specifications and features for the minimum performance standards.

TROUBLE ANALYSIS

Whenever trouble occurs, systematically check fuse, primary power lines, external circuit elements, and external wiring for malfunction before trouble shooting the equipment. Failures and malfunctions often can be traced to simple causes such as improper jumper and supply-load connections or fuse failure due to metal fatigue.

Use the electrical schematic diagram and block diagram, figure 2, as an aid to locating trouble causes. The schematic diagram contains various circuit voltages that are averages for normal operation. Measure these voltages using the conditions for measurement specified on the schematic diagram. Use measuring probes carefully to avoid causing short circuits and damaging circuit components.

CHECKING TRANSISTORS AND CAPACITORS

Check transistors with an instrument that has a highly limited current capability. Observe proper polarity to avoid error in measurement. The forward transistor resistance is low but never zero; backward resistance is always higher than the forward resistance.

For good transistors, the forward resistance for any junction is <u>always</u> greater than zero.

Do not assume trouble is eliminated when only one part is replaced. This is especially true when one transistor fails, causing other transistors to fail. Replacing only one transistor and turning power on, before checking for additional defective components could damage the replaced component.

When soldering semi-conductor devices, wherever possible, hold the lead being soldered with a pair of pliers placed between the component and the solder joint to provide an effective heat sink.

> <u>NOTE:</u> The leakage resistance obtained from a simple resistance check of a capacitor is not always an indication of a faulty capacitor. In all cases the capacitors are shunted with resistances, some of which have low values. Only a dead short is a true indication of a shorted capacitor.

PRINTED CIRCUIT BOARD MAINTENANCE TECHNIQUES

1. If foil is intact but not covered with solder it is a good contact. Do not attempt to cover with solder.

2. Voltage measurements can be made from either side of the board. Use a needlepoint probe to penetrate to the wiring whenever a protective coating is used

on the wiring. A brass probe can be soldered to an alligator clip adapted to the measuring instrument.

3. Wherever possible use a heat sink when soldering transistors.

4. Broken or damaged printed wiring is usually the result of an imperfection, strain or careless soldering. To repair small breaks, tin a short piece of hook-up wire to bridge the break, and holding the wire in place, flow solder along the length of wire so that it becomes part of the circuitry.

5. When unsoldering components from the board never pry or force loose the part; unsolder the component by using the wicking process described below:

(a) Select a 3/16 inch tinned copper braid for use as a wick; if braid is not available, select AWG No. 14 or No. 16 stranded wire with 1/2 inch insulation removed.

(b) Dip the wick in liquid rosin flux.

(c) Place the wick onto the soldered connection and apply soldering iron onto the wick.

(d) When sufficient amount of solder flows onto the wick, freeing the component, simultaneously remove iron and wick.

TROUBLE CHART

The trouble chart is intended as a guide for locating trouble causes, and is used along with the schematic diagram.

The operating conditions assumed for the trouble chart are as follows:

(a) AC power of proper voltage and frequency is preset at input terminals.

(b) Either positive or negative terminal is connected to chassis ground.

TROUBLE SHOOTING CHART

Symptom	Probable Cause	Remedy
1. Zero volts DC output	VOLTAGE ADJ. controls turned fully CCW	Check VOLTAGE ADJ. controls for proper setting and correct as necessary
	CURRENT ADJ. control turned fully CCW	Check CURRENT ADJ. control for proper setting and correct as necessary
	Short circuit across output of supply	Check load and load connections, correct as necessary
	Shorted SCR101 (suffix "OV" models only)	Check SCR101 for short and replace as necesary

TROUBLE SHOOTING CHART (cont'd)

Symptom	Probable Cause	Remedy
	F1 and/or F2 open	Replace F1 or F2; if it blows immediately, check for shorted transistors Q1, Q2 and capacitors C5 and C7, replace as necessary
	Series regulator section open	Check Q1 and Q2 for open, replace as necessary
	Open CR8 or, as applicable, CR11 or CR12	Check CR8 or CR11, CR12 for open, replace as necessary
	Open CR4 or R1	Check CR4 and R1 for open, replace as necessary
	Current sensing resistor open	Check R7 for open, R6 for short; R9 for open; replace as necessary
	Aux. rectifier CR1 open	Check CR1 for open; replace as necessary
2. Unable to adjust output voltage	Damaged VOLTAGE ADJ. controls	Check R8 and R15 for short and/or open; replace as necessary
3. High ripple at line frequency or twice line frequency and unregulated DC output	Series regulator transistors shorted	Check Q1 and Q2 for short and replace as necessary
	Defective main rectifier causes ripple at twice line frequency	Check for open and/or short CR2 and CR3
4. Same as 3, except intermittent	Foreign matter fallen into unit	Check for loose bench hardware and wire clippings that may have fallen through cover
5. High ripple at frequency other than line or twice line frequency	Oscillation due to defective component in filter network	Check for open C7, C2 and check for open and/or short in C8 and R14. Replace defective component
6. Large spikes at output	Capacitors C3 and C4 open	Replace C3 and C4 as necessary

TROUBLE SHOOTING CHART (cont'd)

Symptom	Probable Cause	Remedy
7. Low output voltage unadjustable by voltage controls (suffix "OV" models only)	Fired "OV"	Place power "ON-OFF" switch in OFF position. To resume operation, return switch to "ON" position. Check for shorted Q101, Q102

ADJUSTMENT OF CALIBRATION CONTROL

Whenever parts are replaced, adjust calibration control only when voltage indication is improper and does not reflect maximum ratings.

Adjust Voltage Calibration Control R2 as Follows:

1. Remove AC power input to the supply and place power ON-OFF switch in OFF position.

2. Break seal on wiper of R2 from resistor housing.

3. Operate the power supply for constant voltage connected as shown in figure 1, and no external load.

4. Turn VOLTAGE ADJ. control knobs fully clockwise and, using a DC voltmeter of one percent accuracy or better, adjust R2 to provide output voltage E_0 MAX + 7% of E_0 MAX at 25°C ambient; where E_0 MAX is rated output voltage of the supply.

5. After adjustment is completed, remove AC power input to the supply and reseal wiper of R2 to potentiometer housing.

PERFORMANCE CHECKS

Check the ripple and regulation of the power supply using the test connection diagram shown in figure 4. Use suggested test equipment or equivalent to obtain accurate results. Refer to Specifications and Features for minimum performance standards.

Set the differential meter, DC VTVM (John Fluke Model 801H or equivalent) to the selected power supply operating voltage. Check the power supply load regulation accuracy while switching from the load to no-load condition. Long load leads should be a twisted pair to minimize AC pick-up.

Use a Variac to vary the line voltage from 105-132 or 132-105 volts AC and check the power-supply line regulation accuracy on the VTVM differential meter.

Use a VTVM, Ballantine 320 or equivalent, to measure rms ripple voltage of the power supply DC output. Use oscilloscope to measure peak-to-peak ripple voltage of the power supply DC output.

SERVICE

When additional instructions are required or repair service is desired, contact the nearest office of the Lambda Electronics Corp. where trained personnel and complete facilities are ready to assist you.

Please include the power supply model and serial number together with complete details of the problem. On receipt of this information, Lambda will supply service data or advise shipping for factory repair service.

All repairs not covered by the warranty will be billed at cost and an estimate forwarded for approval before work is started.

PARTS ORDERING

Standard components and special components used in the Lambda power supply can be obtained from the factory. In case of emergency, critical spare parts are available through any Lambda office.

The following information must be included when ordering parts:

1. Model number and serial number of power supply and purchase date.
2. Lambda part number.
3. Description of part together with circuit designation.
4. If part is not an electronic part, or is not listed, provide a description, function, and location of the part.

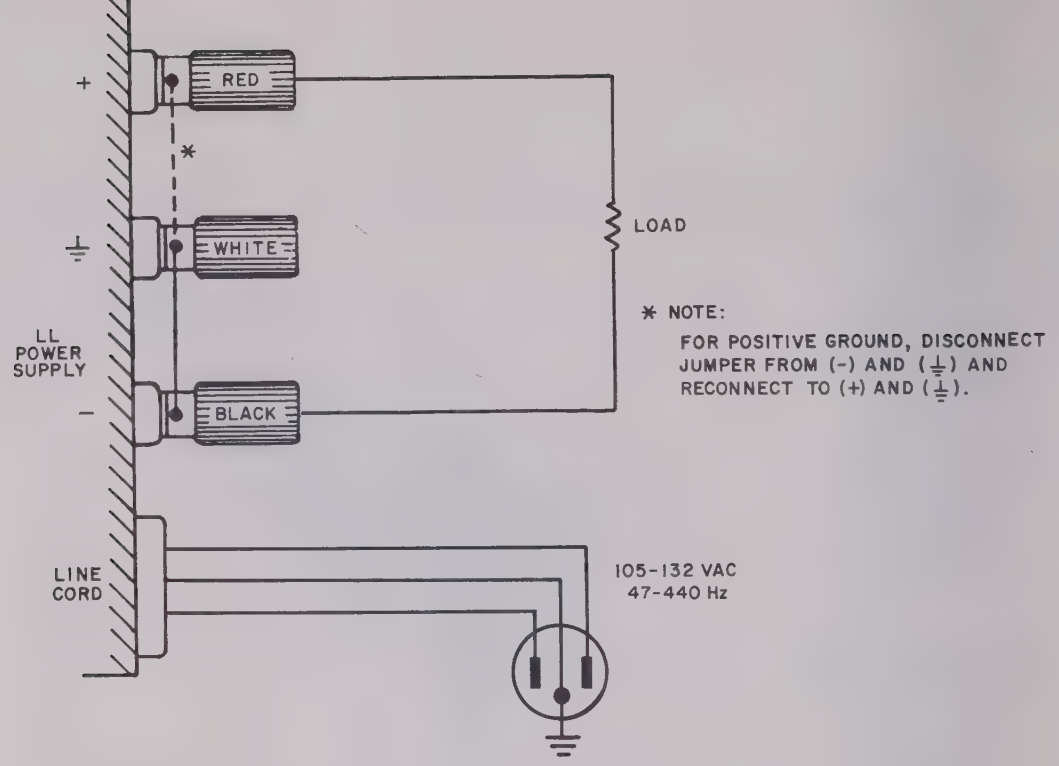


Figure 1. Supply Load Connection.

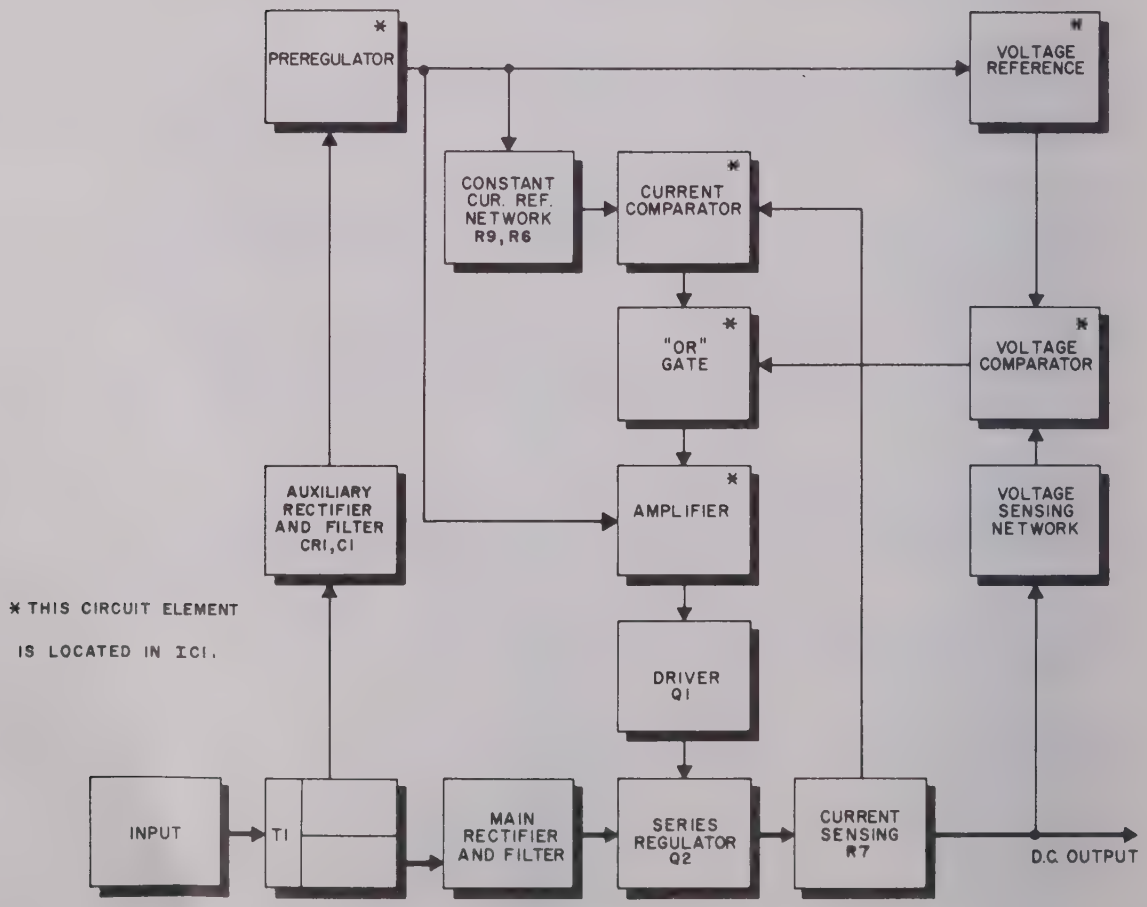


Figure 2. Typical Block Diagram.

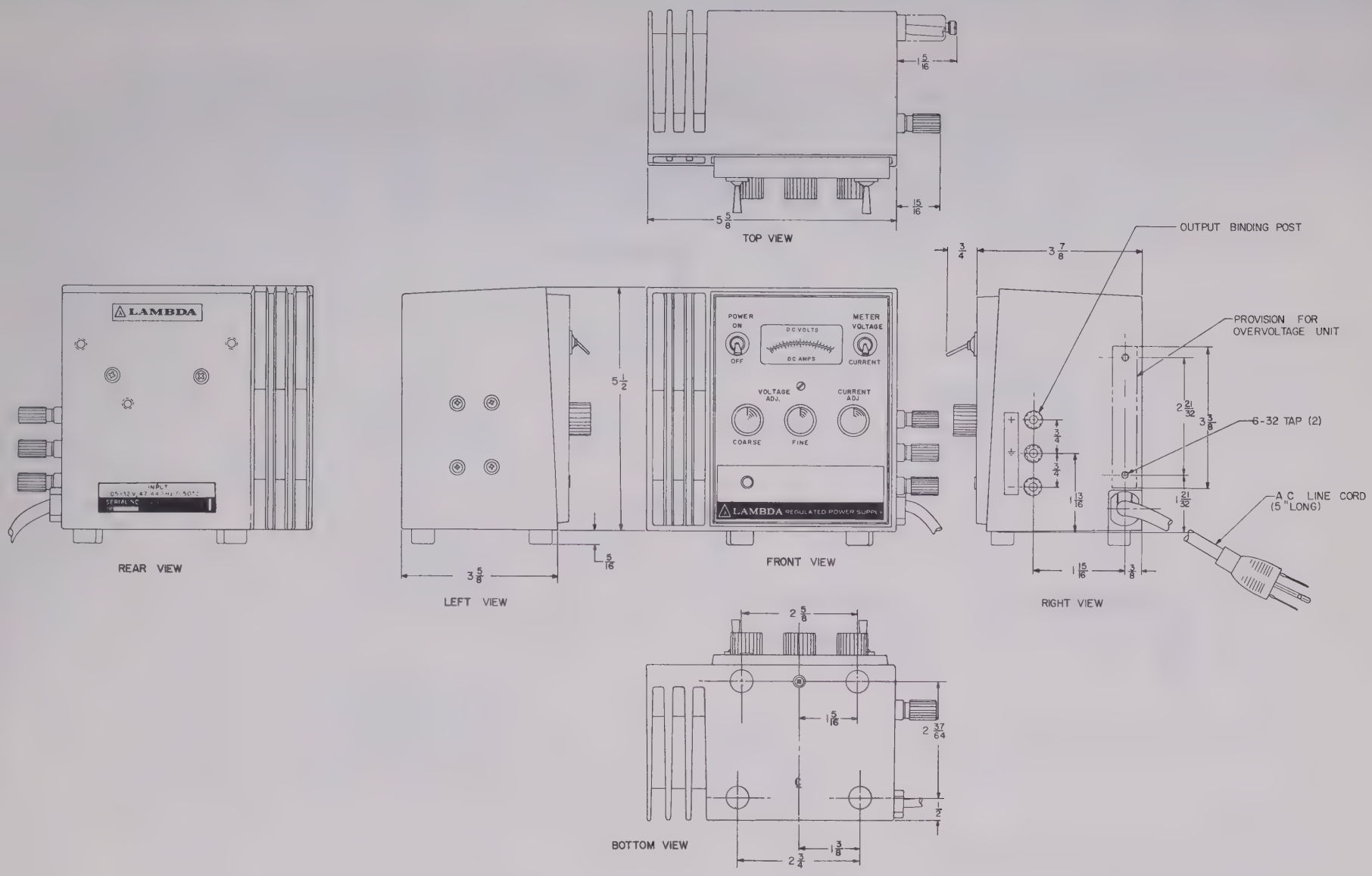


Figure 3. Outline Drawing.

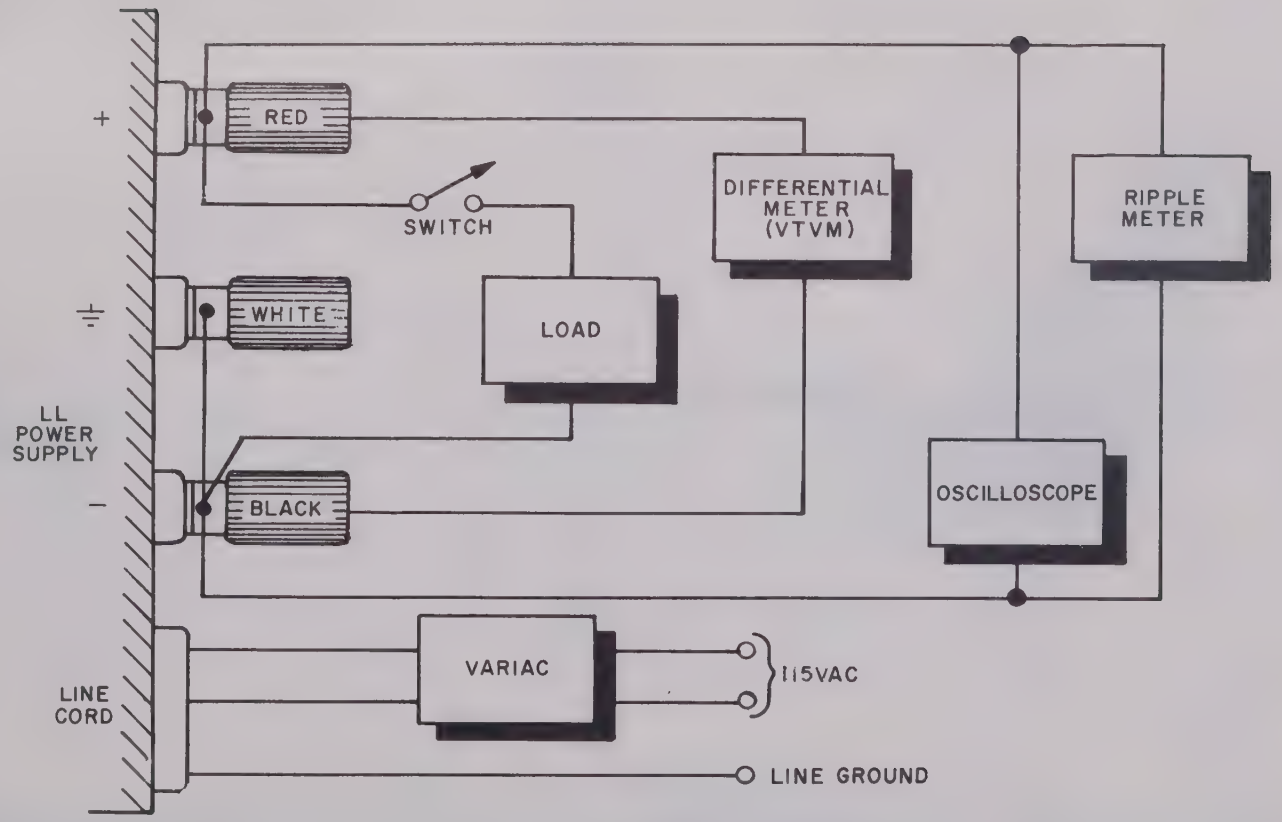
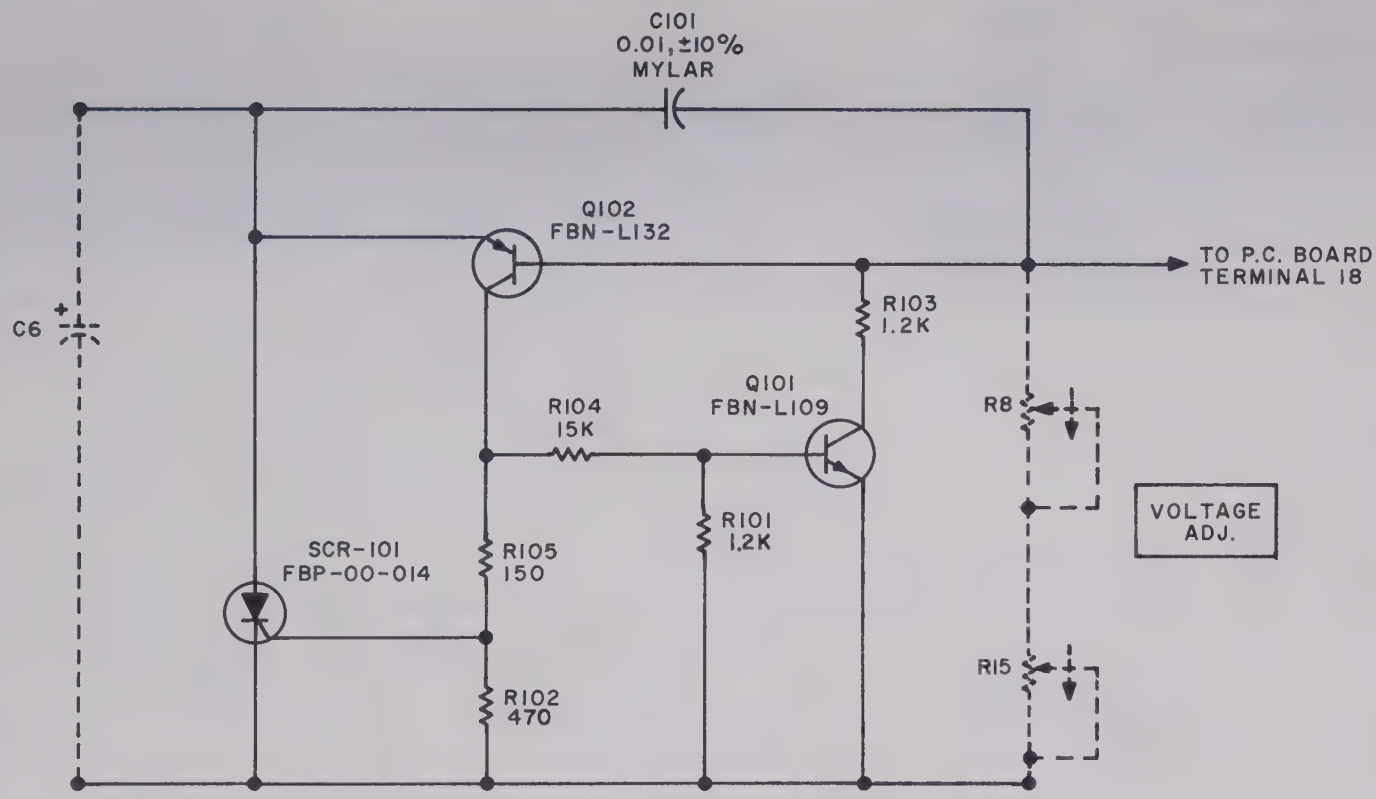


Figure 4. Test Connection For Performance Checks.



NOTES

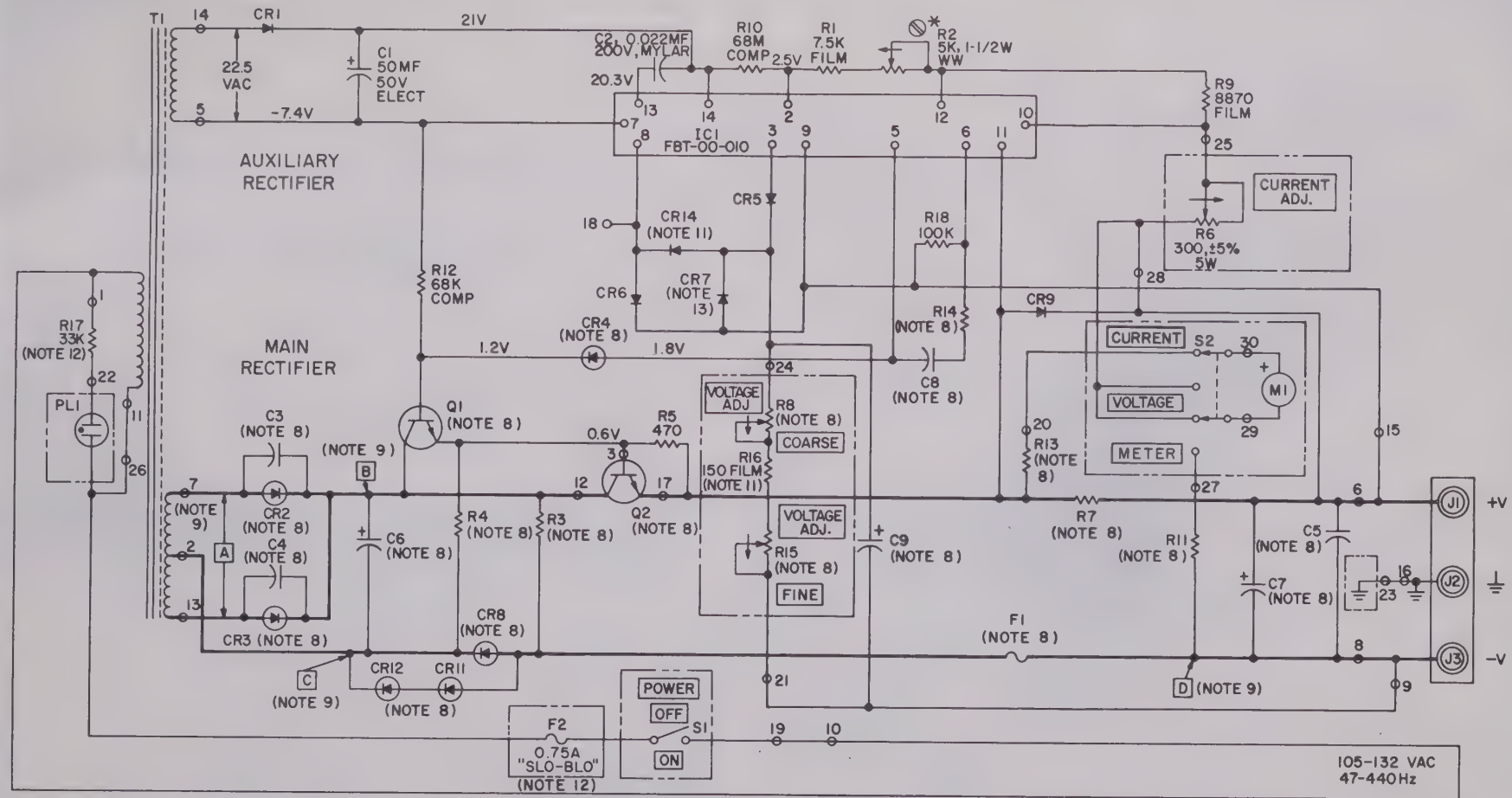
1. RESISTORS HAVE VALUES IN OHMS AND ARE ±10%, 1/2W, COMPOSITION.
2. DESIGNATIONS ARE LAMBDA PART NUMBERS.
3. COMPONENTS IN PHANTOM LINES FORM PART OF STANDARD LL SERIES SCHEMATIC DIAGRAM.

MODELS
LL-901-0V
LL-902-0V
LL-903-0V

SCHEMATIC DIAGRAM

LL OVERVOLTAGE PROTECTION CIRCUIT

LAMBDA ELECTRONICS CORP.
MELVILLE NEW YORK
A Veeco SUBSIDIARY



NOTES:

1. RESISTOR VALUES ARE IN OHMS.
2. RESISTOR WATTAGE 1/4 WATT; RESISTORS ABOVE 2 WATTS ARE WIREWOUND UNLESS OTHERWISE NOTED.
3. RESISTOR TOLERANCES: COMP. ±10%; WIREWOUND ±3%; FILM ±1%, UNLESS OTHERWISE NOTED.
4. CAPACITOR TOLERANCES ELECTROLYTIC -10% +100%; MYLAR ±10%; CERAMIC ±10% UNLESS OTHERWISE NOTED.
5. DESIGNATION IS LAMBDA PART NUMBER.
6. DERATE CURRENT 10% FOR 47-57 Hz INPUT. FOR 63-440 Hz INPUT, CONSULT FACTORY.
7. CONDITIONS FOR CIRCUIT POINT MEASUREMENTS; INPUT: 115VAC, 60Hz; MAX. RATED VOLTAGE NO LOAD. INDICATED VOLTAGES ARE TYPICAL VALUES AND ARE DC UNLESS OTHERWISE NOTED. DC MEASUREMENTS TAKEN WITH 20,000 OHMS/V VOLTMETER BETWEEN +V(J1) AND INDICATED POINTS UNLESS OTHERWISE NOTED.
8. SEE TABLE I FOR COMPONENT VALUES.
9. SEE TABLE I FOR VOLTAGE VALUES.
10. SYMBOLS:
    - INDICATES CLOCKWISE ROTATION OF SHAFT.
    - INDICATES CONNECTION TO CHASSIS.
    - INDICATES ADJUSTMENT OR CALIBRATION CONTROL.
    - SEE INSTRUCTION MANUAL.
    - LAMBDA PT. NO. FBL-00-030, USE IN4002 DIODE FOR REPLACEMENT UNLESS OTHERWISE NOTED.
    - INDICATES TERMINAL ON PRINTED WIRING BOARD.
    - INDICATES FRONT PANEL MOUNTED COMPONENT.
    - INDICATES ACTUAL PANEL MARKING.
11. CR14 AND R16 ARE REPLACED BY JUMPERS ON MODELS LL-901 THRU LL-903.
12. ON UNITS WITH "V" OPTION F2 IS 0.5 AMPS "SLO-BLO" AND R17 IS 100K.
13. CR7 NOT USED ON SUFFIX "OV" MODELS; SEE "OV" SCHEMATIC DIAGRAM.

THIS SCHEMATIC APPLIES TO UNITS BEARING SERIAL NO. PREFIX A

MODELS
LL SERIES

SCHEMATIC DIAGRAM
REGULATED POWER SUPPLY

LAMBDA ELECTRONICS CORP.
MELVILLE, NEW YORK
A Veeco SUBSIDIARY

TABLE I

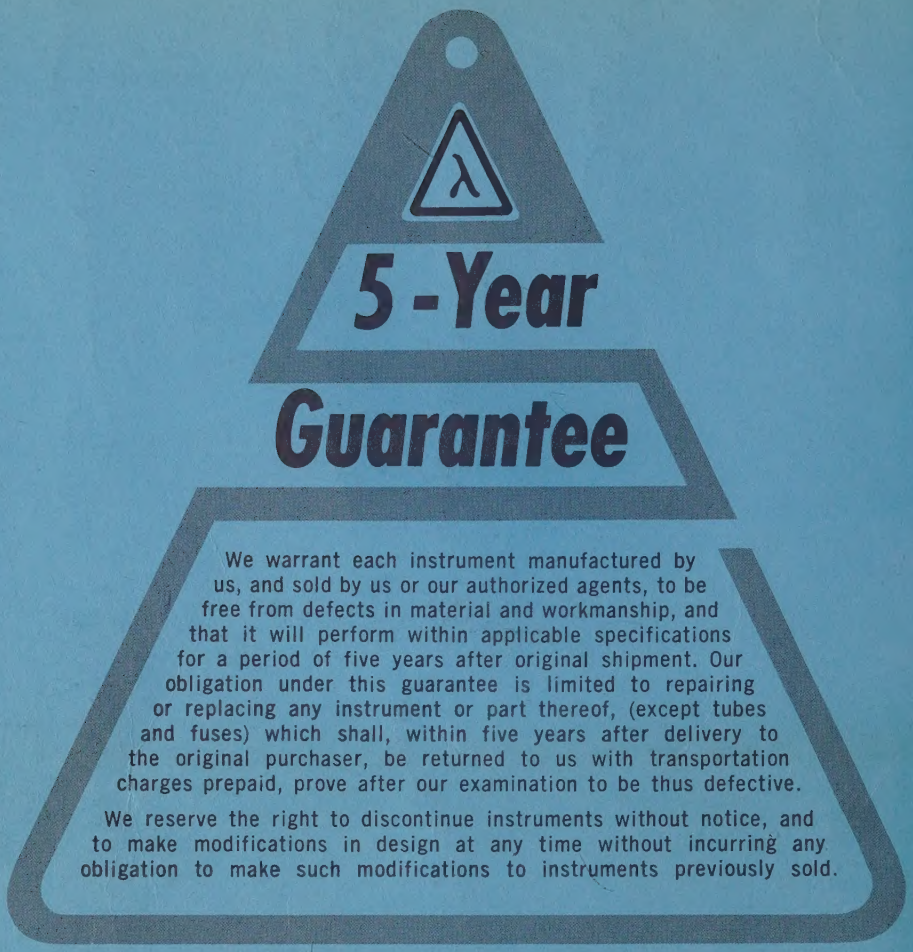
SCHEMATIC DATA REFERENCES
FOR
LL SERIES

Model	Schematic Voltage Measurements				Schematic Components											
	A (VAC)	B (VDC)	C (VDC)	D (VDC)	C3, C4 ±10% MYLAR	C5 ±10% MYLAR	C6 -10+100% ELECT	C7 ELECT	C8 ±10% 200V MYLAR	C9 -10 +100% ELECT	CR2, CR3 *FBL-00-	CR4 *FBL-00-	CR8 *FBL-00-	CR11 *FBL-00-	CR12 *FBL-00-	F1 (AMPS)
LL-901	34	14	-11	-10	0.018 mf 200 V	0.01 mf 200 V	1400 mf 25 V	150 mf -10 +75% 50V	0.0022 mf	2 mf 100 V	063	030	047	Not used	Not used	3
LL-902	60	22	-21	-41	0.018 mf 200 V	0.01 mf 200 V	800 mf 40 V	150 mf -10 +75% 50 V	0.0022 mf	2 mf 100 V	036	036	Not used	Jumper	036	2
LL-903	124	46	-41	-40	0.018 mf 200 V	0.01 mf 200 V	250 mf 100 V	40 mf -10 +100% 100 V	0.001 mf	2 mf 100 V	033	033	Not used	030	033	1
LL-905	248	53	-121	-120	0.0068 mf 400 V	0.0022 mf 400 V	90 mf 250 V	10 mf -10 +100% 300 V	0.001 mf	3.3 mf 250 V	050	050	Not used	030	050	0.5

TABLE I (Cont.)

Model	Schematic Components (Cont.)									
	Q1 *FBN-	Q2 *FBN-	R3 ±10%, 1/2W COMP	R4 ±3% WW	R7 1%, 3W WW	R8	R11 ±1%, 1/4W FILM	R13 ±1%, 1/4W FILM	R14 ±10%, 1/4W COMP	R15 ±5%, 5W WW
LL-901	L113	36485	2.2 K	1.5K 3W	0.25	10 K 5%, 5W WW	10 K	365	680	1K
LL-902	L113	36220	4.7 K	1.5K 3W	0.38	20 K 5% 5W WW	20 K	374	680	2 K
LL-903	L109	36220	22 K	3.6K 3W	0.72	40 K ±10%, 2W CERMET	40.2 K	348	180	4 K
LL-905	L115	38982	220 K	26K 5W	3.8	120 K ±10%, 2W CERMET	121 K	374	180	12 K

*Lambda part number


5-Year
Guarantee
We warrant each instrument manufactured by us, and sold by us or our authorized agents, to be free from defects in material and workmanship, and that it will perform within applicable specifications for a period of five years after original shipment. Our obligation under this guarantee is limited to repairing or replacing any instrument or part thereof, (except tubes and fuses) which shall, within five years after delivery to the original purchaser, be returned to us with transportation charges prepaid, prove after our examination to be thus defective.
We reserve the right to discontinue instruments without notice, and to make modifications in design at any time without incurring any obligation to make such modifications to instruments previously sold.

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